Teaching Resources on the Sustainable Management of Critical Raw Materials

Trainer's Manual for
Closing Loops on Product Level

March 2020

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Table of Contents

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

1 Context and Introduction to Training

This booklet is supplementing the teaching materials and the set of further supporting booklets that have been developed to support teachers in conducting training courses related to the sustainable management of critical raw materials.

SusCritMat aims to educate people from Master's student level up, both in industry and academia about important aspects of sustainable critical raw materials. In a novel concept, it introduces courses on these complex and interdisciplinary topics in a modular structure, adaptable to a variety of different formats and accessible to both students and managers in industry. These courses will develop new skills, which will help participants to better understand the impact and role of critical raw materials in the whole value chain; enabling them to identify and mitigate risks. Understanding the bigger picture and the interconnected nature of global business and society is increasingly necessary to and valued by industry.
SusCritMat is an EU-funded project that brings together the technical and pedagogical expertise of leading educational institutions and business partners. It uses and creates teaching materials which can be combined into different course formats.

This training kit presents the key messages related with the sustainable management of critical raw materials in three major sections:

- Introduction to criticality (including criticality assessment, global resource supply chains, geopolitical factors, and economics of metals)
- Analysis of criticality (including material flows, scenario planning, and life cycle assessment)
- Solutions (including responsible sourcing, circularity indicators, circular product design, and good practice examples)

In particular, the solutions part will be in the focus. The intention is to underline the possibilities that are available to approach and implement a circular economy for critical raw materials and the products bearing these. Doing so the concrete actions, i.e. the things that can be done, are highlighted, instead of only mentioning all sorts of associated problems or barriers in the context of CRMs.

The overall goal of the Summer School for Educators is to qualify the participants to teach the topics themselves. Therefore, the school does not only provide an introduction and improved insight into selected thematic issues, but to also deliver a set of teaching materials "ready-to-use".

- Learning targets that will be reached after having taught the courses
- Presentations on the specific topics including also notes on how to present the slides and key messages.
- Group work exercises including the task or question to work on, if applicable further reading on the methodology and the solutions in case of tasks requiring calculations.
- Assessment questions and the correct answers for each specific topic.
- Additional reading for each topic.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

1.1 Training Materials List

The *SusCritMat project* developed the following teaching materials:

Basics
Critical Resources for Emerging Technologies
Criticality
Supply Chain Resilience
Supply Risk Factors
Circularity
Circular Economy
Characterizing the Urban Mine
Circular Business Models
Waste Management and Recycling Potential
Closing Loops on Product Level
Governance
Geopolitical Aspects
Metals & CRM Scenarios
Restricted Substances Legislation
Impact on Society and the Environment
Sustainability Assessment
Responsible Mining
Responsible Sourcing / Certification
Environmental Aspects
Sustainable Materials Usage
CRM and Sustainable Development
Tools
MFA - Material Flow Management
Good Use of Data
LCA – Life Cycle Assessment
Process Models based on LCA

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

1.2 Timetable

The agenda contains a recommended timing for the lecture and exercises. However, depending on the pre-existing knowledge or group size the time can be extended.

- Circular product design: 1 hour
- Live quiz (questions in Section 4 of this document): 10 minutes
- Discussion on quiz results: 15 minutes

1.3 Key Messages

Design for a Circular Economy emphasises the importance of recovery of products and materials, if possible through maintaining the performance and value of a product over multiple use cycles. Preferred recovery operations are reuse, repair, refurbishment, remanufacturing and parts harvesting, as these processes maintain or restore the functionality of products and parts. Further, enabling recycling of materials is an essential step, although also a last resort. In design this brings about the need for strategic thinking and a long time horizon, with increasing attention to business models.

1.4 Learning Objectives

- You can describe the main characteristics of a circular economy.
- You can compare various circular design strategies to close the loop for a particular product.
- You can explain the importance of business approaches in relation to closing of product and material loops.

1.5 Additional Reading

C. Bakker, M. den Hollander, D. Peck and R. Balkenende (2019), *Circular Product Design: Addressing Critical Materials through Design,* in: World Scientific Series in Current Energy Issues; Critical Materials (Chapter 9), pp. 179-192.

R. Balkenende, V. Occhionorelli, W. van Meensel, J. Felix, S. Sjölin, M. Aerts, J. Huisman, J Becker, A. van Schaik, M. Reuter, *GreenElec: Product design linked to recycling, in: CARE Proceedings, Vienna 2014*

Ellen MacArthur Foundation (2013), *From linear to circular Accelerating a proven concept*, in: Towards a Circular Economy, Part 1(Chapter 2), pp. 21-34.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

2 Slides and Notes

<table>
<tr><td>


</td><td></td></tr>
<tr><td>

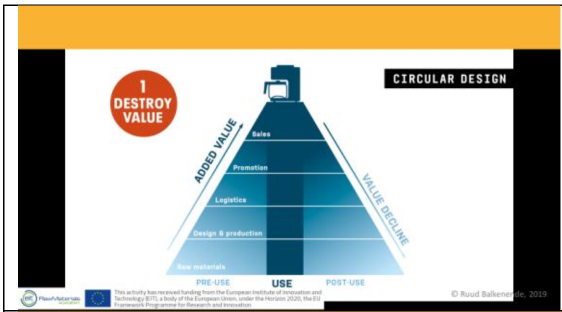

</td><td></td></tr>
<tr><td>


</td><td>Transparent cover of rear light is damaged. Due to thye way the light has been designed this cannot be repaired, but an entirely new module is needed
→ This leads to avoidable loss of value, functionality, materials and energy</td></tr>
<tr><td>

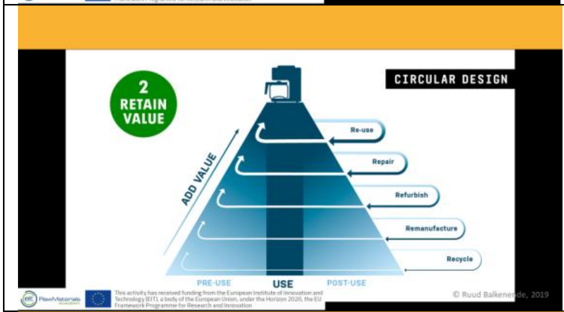

</td><td>Products are made from resources, usually taken from virgin resources. At the end of life products turn into waste. But product design should enable the reuse of products, thus avoiding extraction of resources and pollution of the environment.</td></tr>
<tr><td>


</td><td>Sequence typical for linear economy: take, make, use, waste.
This is directly related to the way products are designed and the business models that are used to put them in the market.
Although some recycling of materials occurs, this is largely coincidental from a design perspective as the ability to separate the materials from which the product is made are not considered during the design stage.</td></tr>
</table>

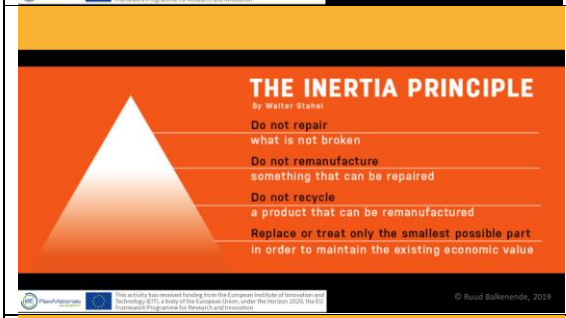
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation



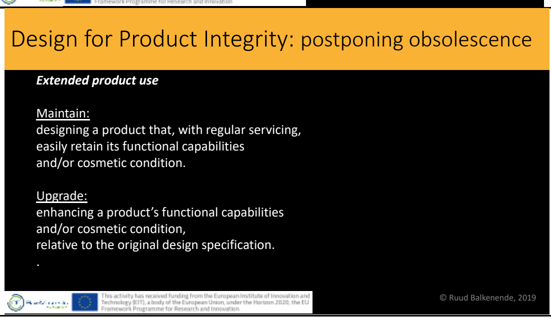
The value loss is depicted in the value hill:
At the end of the use phase almost all value that was initially generated is lost at once.



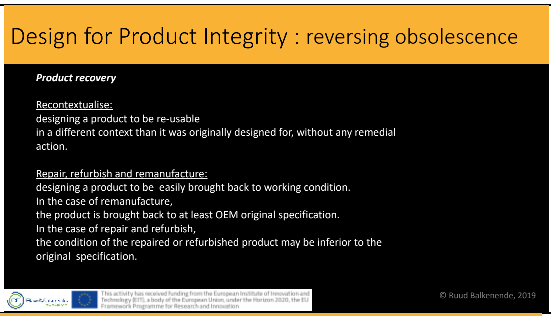
The alternative is that we recover value by keeping products alive, by reusing, repairing, refurbishing and remanufacturing and eventually that we at least recover the materials through recycling.

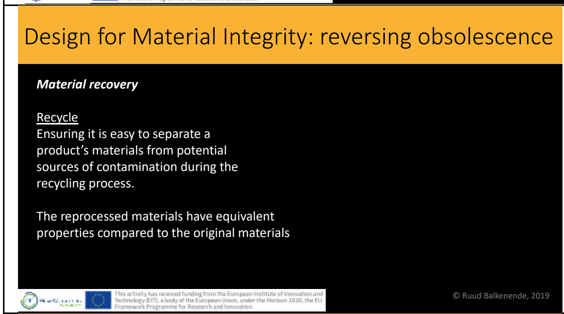


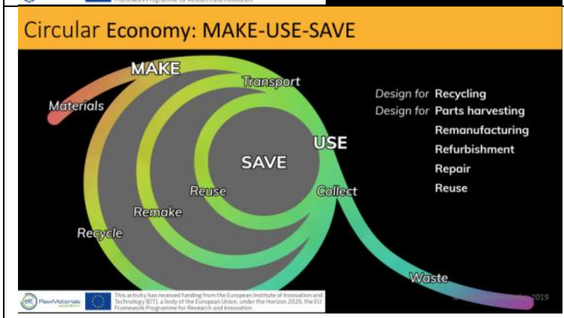
This basically comes down to the Inertia Principle as formulated by Walter Stahel (read).
Maintaining product integrity at the lowest environmental and energy cost is crucial.
Product integrity can be maintained by resisting, postponing or reversing obsolescence.
Let's zoom into the various steps and briefly discuss what this implies for design (next slides).



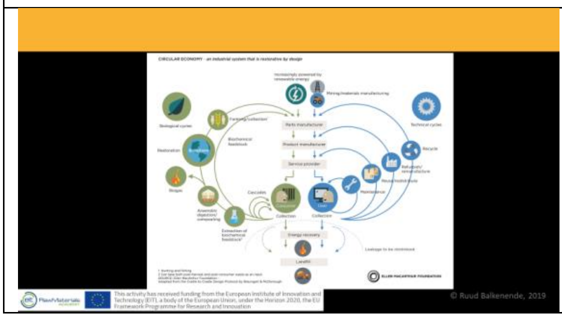
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation







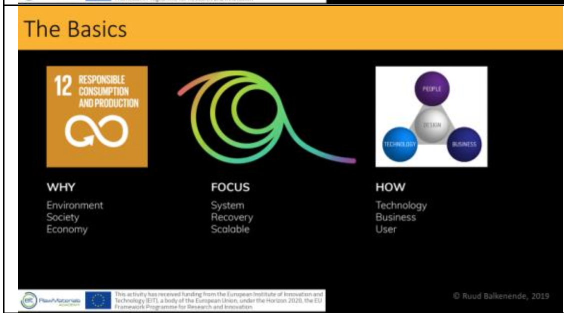
This brings us to an entire set of ways to close the loop and maintain product integrity.
The outer loop of recycling is a necessity to maintain materials, but also should be considered as a last resort, because product integrity is lost. It is important to realize that we cannot just consider this from the technological perspective, but that recovery strategies should also be part of business strategy, as there are many economic incentives for companies to limit the lifetime of their products. In a circular economy it is key to not only design products, but also business approaches hat incentivise avoiding obsolescence. Although not the core of the current presentation some business aspects will be addressed when discussing repair and product-service systems.



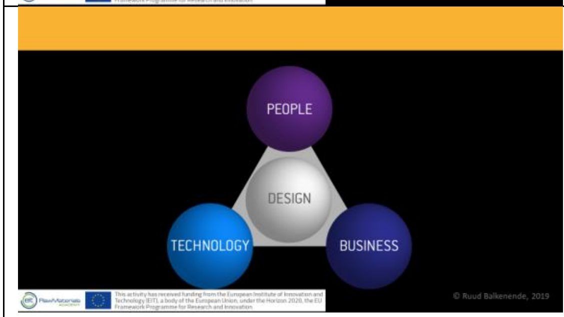
The Ellen MacArthur Foundation distinguishes between a bio-cycle and a techno-cycle in the circular economy. Here we will mainly focus on the techno-cycle, which is especially useful to consider more durable and complicated products. But realize that the cascading way of dealing with renewable materials as depicted in the bio-cycle is a very interesting approach for especially fast moving consumer goods.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Let’s first take a step back and look at the principles underlying a circular economy. These are related to the SDGs, and for design especially SDG 12 on responsible consumption and production is important.



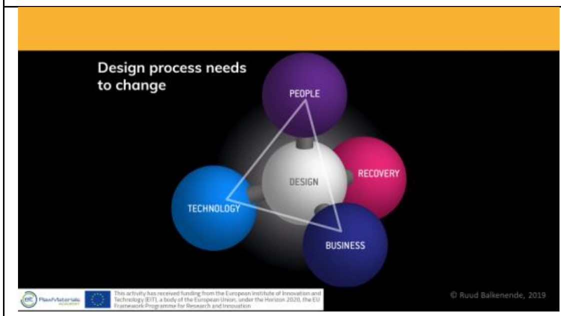
Basics for designing products for a circular economy can be found in the triple bottom line on sustainability, Main challenges are to consider impact at system level, taking recovery into account and reaching a large scale. Designers approach this by integrating human, societal, business and technological perspectives by exploring solutions.



Circular Product Design

With user, business and technology, we have the three pillars of design as we distinguish them within the field of industrial design engineering. But our current way of designing misses out on sustainability. Therefore, two basic questions are:

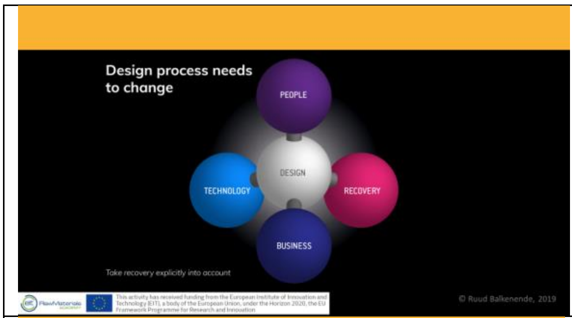
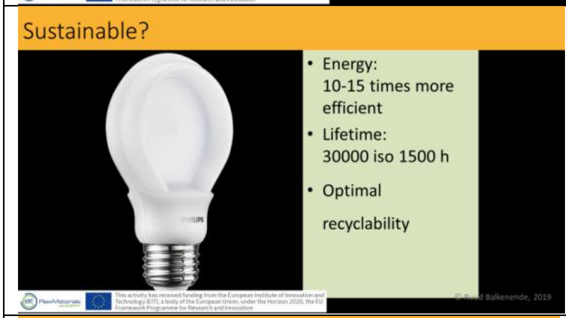
- What should we do differently in the design process of products and services to make sustainability considerations an integral part of design?
- And how can we implement this in the actual design process as it takes place within companies?



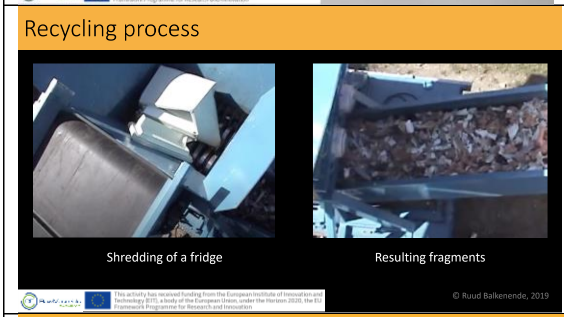
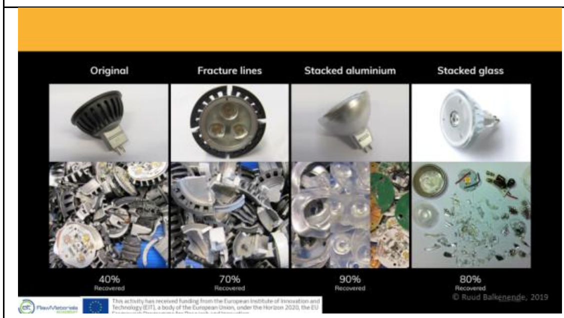
Explicitly address Recovery

To answer that, let’s look again at the design triangle. The focus is on how to design a product, applying technology, in such a way that it is interesting to manufacture and attractive to a user, considering things like the manufacturing process and cost, the performance, quality and price of a product. But what happens when the performance of a product is no longer desired by the user? In this model it is not considered how we can recover a product. So, we have to change our perspective and then we will see that this triangle is actually the face of a pyramid that also includes recovery, that is; all actions that might be needed after disposal of a product to reverse its obsolescence. What we should add to the design process is thus to explicitly take into account the treatments at the end of a product lifecycle, so that we can start a new lifecycle instead of wasting the product.

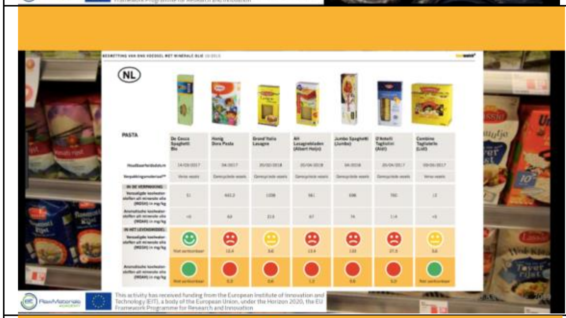
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

	How can we achieve this? Here many answers and approaches are possible. I will in the following mainly focus on some different approaches.
	Let's start this with some quizzing; Which lamp is most sustainable: the left LED-lamp or the right incandescent lamp. (hand raising)? (Text provides benefits LEDs): in this case applying new technology was driver.
	Left chair or right one. (Text provides benefits Herman Milllar chair): in this case design choices enabled recovery.
	Left or right pair of jeans? (Text provides benefits Mud Jeans): in this case attention to fair sourcing of materials, but main differentiator is the business model that stimulates recovery. So, we have now seen examples in which respectively technology, design choices and business model had emphasis, but in practice these 3 are usually closely related.
	Let's now go into some more detail and start by looking into recycling.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

	This is a flashlight with solar cell and the result after shredding. The fragments have mixed compositions and the value is then negative, as disposing the materials costs money. How can we improve on this?
	Looking at the recycling process, we should first realize that recycling is a rough destructive mechanical process. Almost all consumer goods, whether it is a phone, a hairdryer or a fridge, end in this way. So, designing for recycling means that we need to know what happens during the most likely recycling processes.
	Let's take an electronic product, in this case a lamp, and see what happens when it goes through a shredder. We get fragments that still contain many different materials that cannot be recycled simultaneously. The electronics largely remain fixed to the aluminium heat spreader and during separation will likely end in the aluminium fraction. This not only contaminates the aluminium stream, but also causes the loss of copper and other precious metals present in the electronics. With this specific product about 40% of the weight is recycled, mainly because we have quite a lot of aluminium, which is quite easily separated.
	The results presented here are based on a study within Philips. A number of different strategies was followed to improve recyclability. The most simple one, hardly involving any changes in the manufacturing process: fracture lines in the aluminium heat spreader. As the aluminium and electronics remained fixed due to a screw connection, an obvious line of thought is: breakdown the screw connection during shredding. Without compromising reliability of the lamp during its operating life, this can be done by introducing fracture lines in the heat spreader. The results in a shredding test are very convincing: almost all PCBs are released and can be separated and recycled. So, this is a great improvement at exactly the same cost in manufacturing. By really redesigning the lamp, in one case removing all internal connections, in the other case by using a brittle housing and removing

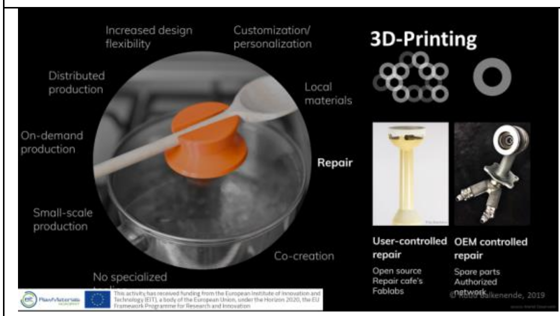
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

	internal connection even better results are obtained.
	However, when products are not made for recycling, using the recycled materials can be tricky. Here an example of tires which were grinded and used as a kind of additive on artificial lawn. When it became clear that these particles contain carcinogenic materials and that children are playing on them, this became a big issue.
	Also recycled cardboard can be contaminated with chemicals, for instance from printing ink, that subsequently was shown to contaminate food. This doesn't show that we shouldn't use recycled materials, but it demonstrates that *we need to take the recyclability of materials into account already when we design the original product*.
	*Let's step from the outer loop to the inner loops; from material recovery to product integrity.* To recover not only materials, but also functionality and value, we need to close the loop at the level of the user, the level of a service provider or the level of the manufacturer. Although on a technological level repair and refurbishment can be enabled, for actual implementation combined action involving business approach and user behaviour is required.
	Let's take as an example for repair two different smart phones. Fairphone pays special attention to the sourcing of its materials, thus emphasising a social aspect of sustainability. The phone is further built in a modular way, with a relatively low level of integration and easy accessibility of all modules. This allows easy repair or even upgrading of parts by the user. This should allow the phone to be used for at least 4 years, which is about twice the average for smart phones. Apple has a durable design, to a lower extent even modular, but accessibility of inner pats is made very difficult.
	The interior of the iPhone is almost inaccessible unless you take special actions that are beyond the abilities of an ordinary user. Even if you get to the interior level, integration and the way in which modules are connected make this product almost impossible to repair for the user. However, due to the high quality of its built and the parts used, as well as the appeal of its design to users, the product is durable and also

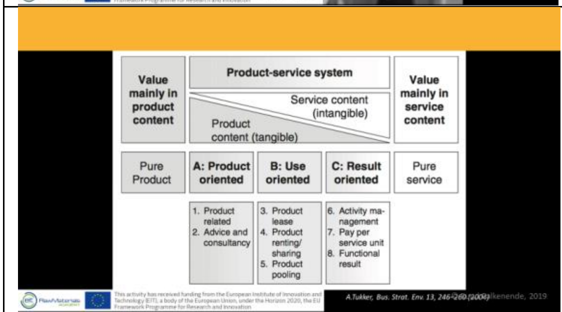
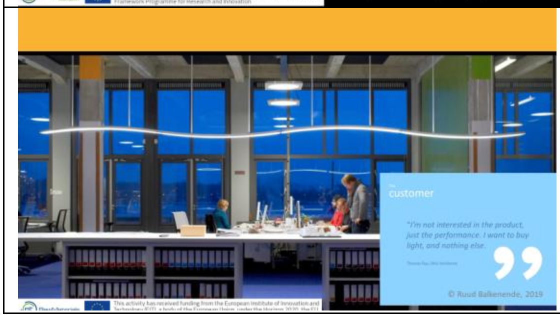
eit RawMaterials ACADEMY
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

	considered attractive as refurbished product in a second life. From a technological perspective both companies have followed completely different routes towards a longer than average product lifetime. Which approach is preferable from a sustainability point of view?
	***Responsibility and empowerment*** Interestingly, both approaches can be valid. It will depend on the business model as well as on the behaviour of the user. Fairphone targets users that are motivated and enables those users to prolong the lifetime of their products. Fairphone enables users who want to take responsibility. But basically, products that are built in this way can and probably will be repaired by most users. The disadvantage might be that consumers can tweak the phone, thus risking performance issues. Also, in heavy-duty situations the easy accessibility might conflict with reliability. But anyhow, Fairphone explicitly has taken into account in its design what actions to enable when a product becomes obsolete. This also creates awareness with users. Apple targets users that go for a slick high-end phone, which is built for performance. In many cases the product will be used for 1-2 years and then be transferred to another user for a similar time. However, when the product breaks down and needs repair after expiration of the warranty period the only thing that is clear, is that repair will probably be very expensive. So users dispose of their phone and only a limited number will be refurbished. The users are not triggered to awareness of sustainability and Apple doesn't empower their users to prolong the phone's lifetime. It is not clear to the user which action needs to be taken to extend the product lifetime when the product becomes obsolete. The user is made responsible, but has no means to determine the most appropriate actions. Apple therefore should take that responsibility, which for instance could imply prolonging the warranty period to e.g. 5 years or to make the phone part of a service systems, in which Apple keeps the final responsibility. Such steps, by the way, will probably lead to some changes in the design of the product to enable e.g. easier repair and refurbishment. Two completely different design approaches, both can be successful from the perspective of lifetime extension. But to be successful, they should both explicitly take into account the recovery opportunities for recovery at the end-

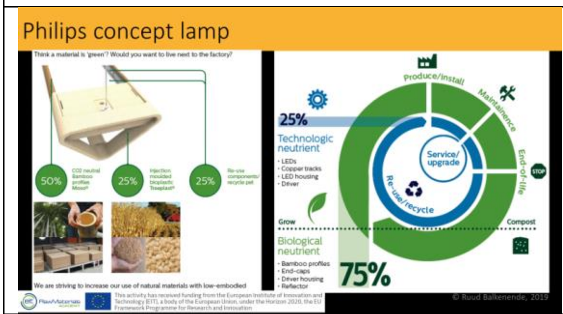
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

	of-life of the product. And that does not only mean technological feasibility, but also enabling those who are responsible for the recovery process, either through enable self-repair, or by enabling transparent and affordable professional repair.
	In the two phone examples shown we recognize different strategies towards a more sustainable design. Fairphone aims for ease of maintenance and repair, focuses on dis- and reassembly and the design benefits from standardization and compatibility. Apple makes a relatively robust and product, focusing on durability and through its iconic design creates attachment. It will be dependent on the user target group and the business model which strategies are most useful.
	3D printing is often claimed to be a solution for CE. However, things like local production and personalization do not automatically lead to a reduced environmental impact. But 3D printing does offer interesting possibilities for repair as in that case the ability to take local action makes sense, e.g. by the opportunity to locally print spare parts. Different design approaches are needed for professional parts (via certified partners) and non-professional repair (with potential liability issues). In the latter case design enabling such repair should take into account safety aspects. Currently this isstill explorative, but demonstrating high potential versatility. The examples in the next sidesd have been taken from a series of repaired products demonstrated by Marcel den Hollander and Conny Bakker under the name 'Value Added Repair'.
	Some examples. Broken handle.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

	The handle in this case is not just repaired, but also has improved grip. This illustrates that 3D printed repair can also be used to improve or customize a product
	Broken and repaired tea set.
	Another example from the same series with the broken grip from a lid, were the grip has been replaced by a grip that also holds a spoon.
	In the previous part we focused on tangible products, but it is very worthwhile to expand our view from products to product-service systems. If the pure product would be a car, the product-oriented service might be a maintenance contract, a use-oriented service would be leasing or renting a car, while a taxi-service would be result oriented. The pure service would just be transportation from A to B.
	An example is Light-as-a-Service, in which the manufacturer keeps ownership, is responsible for maintenance and end-of-life treatment and even the energy bill. This shift of responsibility during and after use, leads to different design incentives. First example office of architect Thomas Rau. Now also a departure hall at Schiphol Airport.

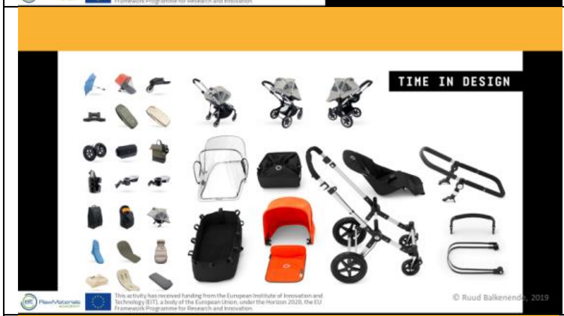
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

	(text on slides shows some service details)
	Customers want Philips to ensure hassle-free operation of their lighting equipment, with a lower operating expense and a guarantee of current technology without capital investment. Clients are very interested in achieving certain business outcomes and want Philips to be 'in the game' sharing risk and assuring positive returns. Many customers have challenging sustainability targets. Philips can support them by adding a Circular Economy dimension through the concept of 'Light as a Service'.
	Different design incentives for the light sources. Shown here is a concept product that illustrates this. Different materials: recyclable or renewable Energy efficient LEDs Modular built with most vulnerable parts easy accessible for repair Longer lifetime, mainly through higher performance electronics
	Resulting concept lamp. This lamp is modular in built, with even the ability to replace just the LED-strip for one with other colour temperature or a higher efficiency
	Another example of a product-service system: easy access to bicycles that are widely available all over a city. Especially very popular with students who don't need to care about parking their bike, which is too often stolen. The bikes should be robust and also other aspects of the design are tweaked, like the luggage carrier at the front instead of at the rear, which prevent overloading by dual occupancy.

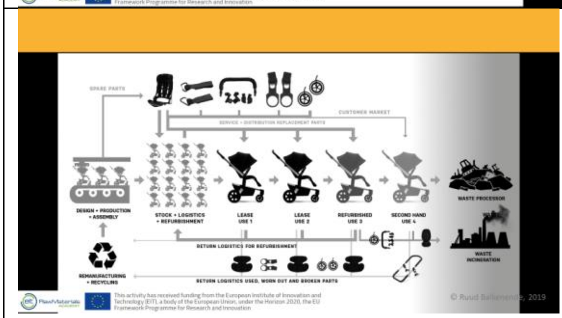
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

However, this service is not necessarily sustainable. Often too cheap bicycles are used with a life time just sufficient to make a nice profit. Then this type of service can actually become rather wasteful. Again, business model and design should have circularity at the core of their strategy to make this a worthwhile proposition from a sustainability perspective.

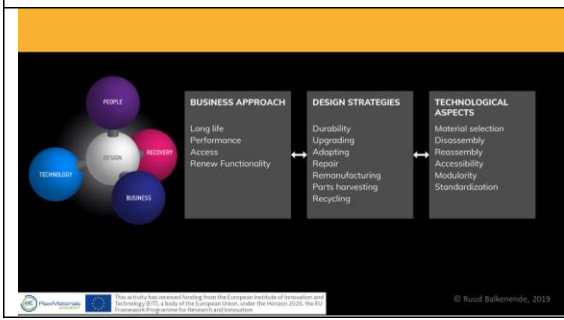
Taking recovery and preferably continued functional performance as a key strategic principle leads to a new design challenge that needs further exploration: considering the behavior of a product over time, taking into account that products should have multiple life cycles. This poses challenges at different level. Here highlight one.



As an example we will take a stroller. This product consists of many different parts, all with their own aging behavior and lifetime.



To achieve multiple lifecycles not just look at the product, but also at the service. As an example, in this case we could choose for a cascading business model: high-end product during first use, and then cascading to lower-end in subsequent leases. At every lease some parts need to be replaces and some refurbishment might be necessary. To optimize this from a business perspective, lifetimes should be matched to (multiples of the) lease period.



Aligning business model with design strategies and technological approaches is key to circular design.
As this is not an easy thing, this slides actually stresses that experimenting, exploring and learning is key. Learn through small scale experiments.
Crucially for designers: take multiple lifecycle into account through the entire design process.

eit RawMaterials ACADEMY
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

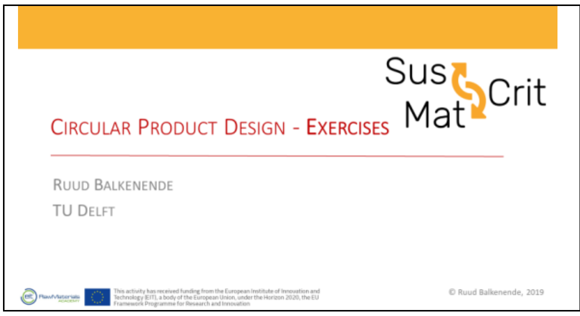
3 Exercises

Exercise 1
Find two examples of businesses that are "going circular".
Give a one-sentence description, and indicate which part of the butterfly diagram they belong to. Provide a link to a website or video if possible.

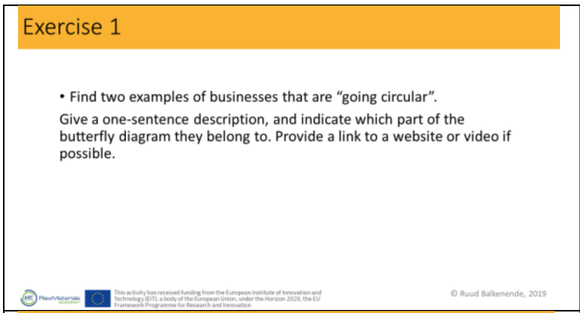
Exercise 2
Develop a set of 5 repair criteria.
These criteria should be usable for a wide range of products, not just for bicycles, for instance.

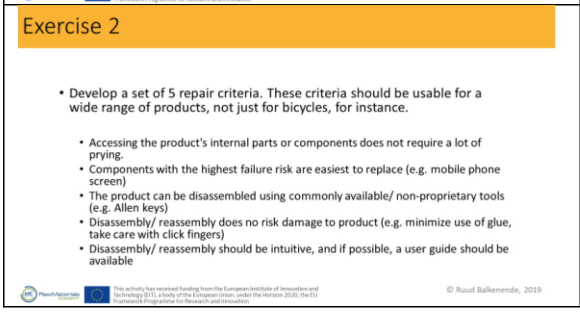
1. Accessing the product's internal parts or components does not require a lot of prying.
2. Components with the highest failure risk are easiest to replace (e.g. mobile phone screen)
3. The product can be disassembled using commonly available/ non-proprietary tools (e.g. Allen keys)
4. Disassembly/ reassembly does no risk damage to product (e.g. minimize use of glue, take care with click fingers)
5. Disassembly/ reassembly should be intuitive, and if possible, a user guide should be available

Slides:



This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation





4 Assessment questions

1. Which of the following statements is <u>not</u> typical of a linear economic system? (check all)
   A. Cheap materials, cheap energy, cheap credit
   B. Three billion new customers will enter the market in the next decades (correct)
   C. Nature is a source of raw materials and a 'sink' for our waste.
   D. Take-Make-Use-Waste

2. What is the meaning of the **Inertia Principle** in the Circular Economy?
   A. Resistance to the change from the linear to the circular economy.
   B. Keeping products at their highest economic value for as long as possible. (correct)
   C. An alternative way to express the principle "Energy from Renewable Sources".
   D. The idea that repairing requires more energy than remanufacturing, which in turn requires more energy than recycling.

3. The Inertia Principle gives a priority order for treatment of end-of-use products. The correct order, from left (highest priority) to right (lowest priority), is:
   A. Remanufacture – Repair – Recycle
   B. Repair – Remanufacture – Recycle (correct)
   C. Remanufacture – Recycle - Repair
   D. Recycle – Repair - Remanufacture

4. What is the correct term for a strategy that aims to artificially shorten product life?
   A. Product lifecycle management

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

B. Product portfolio management
C. Planned obsolescence (correct)
D. Concurrent engineering

5. A European law discussed the requirement that all cell phones must charge through a common standard, in other words: one type of charger for any mobile phone. Designers had to take that requirement into account. This is an example of: (*choose the best, single option*)
   A. Design for product attachment and trust
   B. Design for product durability
   C. Design for standardization and compatibility (correct)
   D. Design for ease of maintenance and repair
   E. Design for upgradability and adaptability
   F. Design for disassembly and reassembly

6. Zipcar is a business that offers cars by the hour or day. You pay a membership fee and a driving rate (per hour or day). The driving rate varies per car, with luxury cars costing more. This is an example of a:
   A. product-oriented model
   B. use-oriented model (correct)
   C. result-oriented model

7. Using discarded fishnets as a source for carpet tiles is an example of:
   A. Repair
   B. Recycling (correct)
   C. Remanufacturing
   D. Nature-inspired design

8. At the moment the global demand for aluminum cannot be met by recycling alone. Why is this the case?
   A. Global demand is still growing (correct).
   B. There are not enough aluminium recycling facilities.
   C. Aluminium cannot be recycled.
   D. The modern uses of aluminium differ too much from traditional use.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

5 Acknowledgements and Authors

Ruud Balkenende from TU Delft prepared the teaching material for Session IX.

The following authors have prepared the complete teaching material kit for the SusCritMat Summer School for Educators and intend to provide an overview of major topics surrounding the sustainable management of critical raw materials:

Ruud Balkenende, TU Delft
Stefano Cucurachi, Uni Leiden
Andrea Gassmann, Fraunhofer IWKS
James Goddin, Granta Design
Dominique Guyonnet, BRGM
Alessandra Hool, ESM Foundation
Thibaut Maury, University of Bordeaux
David Peck, TU Delft
Dieuwertje Schrijvers, University of Bordeaux
Layla van Ellen, TU Delft
Tatiana Vakhitova, Granta Design
Ester van der Voet, Uni Leiden
Patrick Wäger, Empa
Steven Young, University of Waterloo

Besides, many others invested their time and expertise to discuss and review the teaching materials. Many thanks to:

Conny Bakker
Sonja van Dam
Marcel den Hollander
David Peck

6 Citation

Please cite the SusCritMat teaching material as follows when using them for your curriculum:

SusCritMat – Sustainable Management of Critical Raw Materials, funded by EIT RawMaterials, April 2017 – March 2020.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

7 Disclaimer

The teaching materials within the SusCritMat project have been prepared with great care and experienced several revisions. Nevertheless, the consortium assumes no liability for the topicality, completeness and correctness of the content provided.

In case you have suggestions or other feedback how to improve the materials, we value your opinion: Please contact us via the project webpage https://suscritmat.eu/contact/.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation